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AFFSE REPORT 2/87

EXTERNAL CORROSION OF TINPLATE RATION FOOD CANS UNDER TROPICAL FIELD STORAGE

(U)

P. J. CAVANOUGH

P. W. BOARD

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Postal Address: The Officer-in-Charge,
Armed Forces Food Science Establishment,
P.O. Box 147,
Scottsdale, Tas. 7254

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INTRODUCTION

A. Purpose of the Study

For some years there has been the trend in the Australian canning industry to use tinplate cans having lower tin coating mass. This cost saving development is acceptable, providing corrosion does not penetrate through the can with the subsequent risk of spoilage, nor detracts from the cosmetic appearance of the can. Hartwell (1956) states that the obvious standard for the exterior of a can is that it be acceptable to the consumer for as long a period as the interior of the can is satisfactory. Essentially the exterior is acceptable as long as it is substantially rust-free.

At recent Australian Defence Force Food Specifications (ADFFS) Committee meetings, submissions were received from some canners and canmakers for the use of the lower external tin mass coating of 2.8gm^{-2} nominal (termed 05), on Australian Defence Force canned rations. Due to a lack of information on external corrosion of 05 tin plate under field conditions, the ADFFS Committee approved continuation of the survey on can performance by the Armed Forces Food Science Establishment using the facilities of the Joint Tropical Trials Establishment (JTTRE), Queensland, for field evaluation.

B. Previous Studies

There is a little published research on the external corrosion of 05 tinplate cans. Guild (1981) reported that 05 tinplate does not perform as well as 10 (5.6gm^{-2}) tinplate in cans exported to tropical countries. He added that 05 tinplate is not satisfactory, where climatic conditions are conducive to rust formation, and where warehousing conditions are poor.

Beyer (1985) reported that externally lacquered cans, which had not been subjected to the rigors of transportation, when tested in a temperature cycled, humid environment, were resistant to corrosion. However, a small number of samples obtained from ration packs following normal distribution, showed rusting near the end hook and side seam after 4 days in similar cycled conditions. This is in agreement with the views of Board & Steele (1975), who stated that external lacquering or lithography cannot be relied upon to protect cans from rusting. They further stated that rusting of cans in transport and storage is usually caused by water condensing on the cans from the environment, when the can temperature is less than the dewpoint of the air. Hartwell (1956) suggested that temperature and humidity are probably the most important factors inducing rusting during storage.

* CSIRO Division of Food Research, North Ryde, N.S.W.

C. Scope of the Present Study

This trial was designed to assess the nature and extent of external rusting on 05 tinplate ration pack cans during field storage in a tropical environment. The study was also designed to corroborate views of Bell (1986) that externally decorating a can reduces corrosion, and of Beall & Cassady (1955) that postcoating cans affords maximum protection for tropical storage.

MATERIALS

Materials Used

The test products were commercially manufactured ration pack cans [ADFFS (1986)] of:
Green Peas (ADFFS 7-1-11), 74 x 112.5mm cans, unlacquered externally.
Mushrooms (ADFFS 7-1-25), 74 x 61.5mm cans, lacquered externally.
Beef & Vegetable Stew (ADFFS 5-3-12), 99 x 68.5mm cans, lacquered externally.

The cans were fabricated from tinplate with an external nominal tin coating mass of $2.8 gm^{-2}$ (05 designation), with the exception of Pea can ends, which had an external mass of $5.6 gm^{-2}$ (10 designation).

The cans of Mushrooms and Beef & Vegetables were dip lacquered, after processing, with a petroleum solvent lacquer as specified in ADFFS 15-6-1 (1979).

The test cans (3,200 total) were packed in commercial corrugated cartons, each containing two layers of twelve cans. Except for the peas, the layers were separated by solid cardboard liners of 0.8mm thickness.

METHODS

A. Location of Study

Half of the cans of each product were sent to the Armed Forces Food Science Establishment (AFFSE), Scottsdale, Tasmania and the remainder were sent to JTTRE in North Queensland.

Figure 1 shows the relative location of both Establishments.

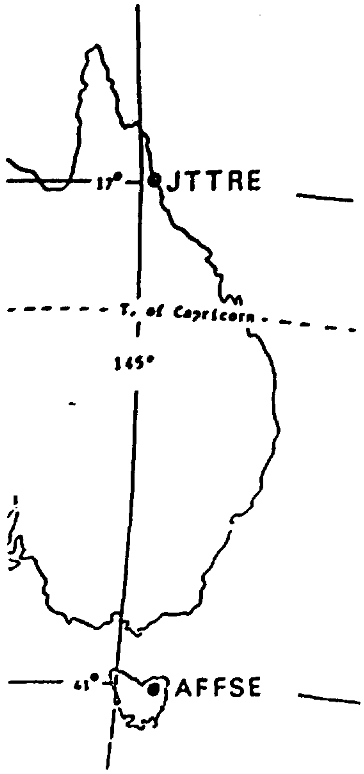


Fig. 1. Locations

This field location was chosen to represent a region, with relatively corrosive atmosphere, where food storage may be required in an operational situation. The JTTRE Cowley Beach site is located 17°41'S and 146°06'E, in a hot, wet tropical zone, with appreciably saline conditions. The average annual rainfall of 2900mm falls predominantly from December to May. In contrast, the storage conditions of temperature and humidity, could be controlled at the AFFSE laboratory.

B. Transportation

The normal road distribution system was used, involving commercial delivery to Army Supply, thence Army transport to Cowley Beach. The Peas were processed in Northern Tasmania, the Beef & Vegetable Stew at Wagga Wagga and the Mushrooms at Bathurst, N.S.W.

C. Storage Treatments

As shown in Photo 1. and in Fig. 2, cartons of each product were stacked three or four cartons high on standard wooden pallets in double rows (numbered I and II), under two types of canvas cover. Six stacks were tightly covered by standard olive drab tarpaulin (termed 'close wrap') and the corresponding six stacks were covered by the standard tarpaulin erected in the manner of a tent (termed 'tent cover') as described in RAASC (1971). The cans remained on trial for 23 weeks from 21 December 1984 to 29 May 1985.

The degree of external corrosion occurring on the can bodies and ends in all the stack positions was assessed after 23 weeks' storage. The data for the areas of rust, as a percentage of the surface area of the can body and ends were analysed by analysis of variance to assess significant differences within lacquer treatments and storage conditions.

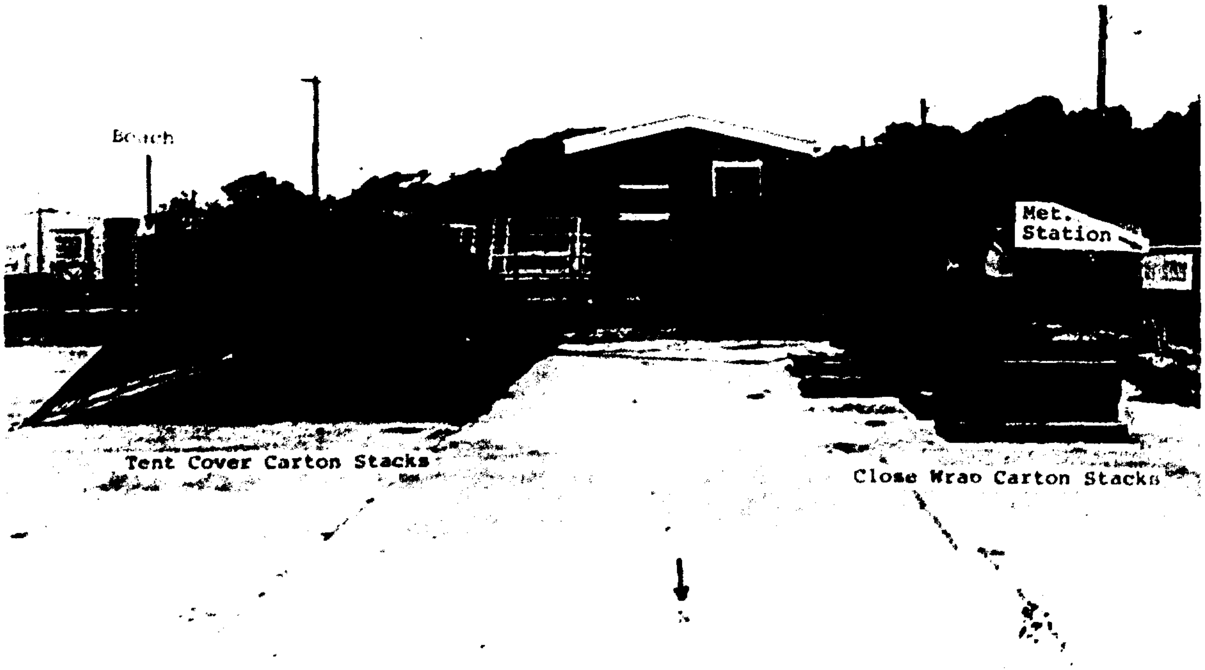


Photo 1 Cartons of cans, stacked in rows under the two variations of tarpaulin cover.

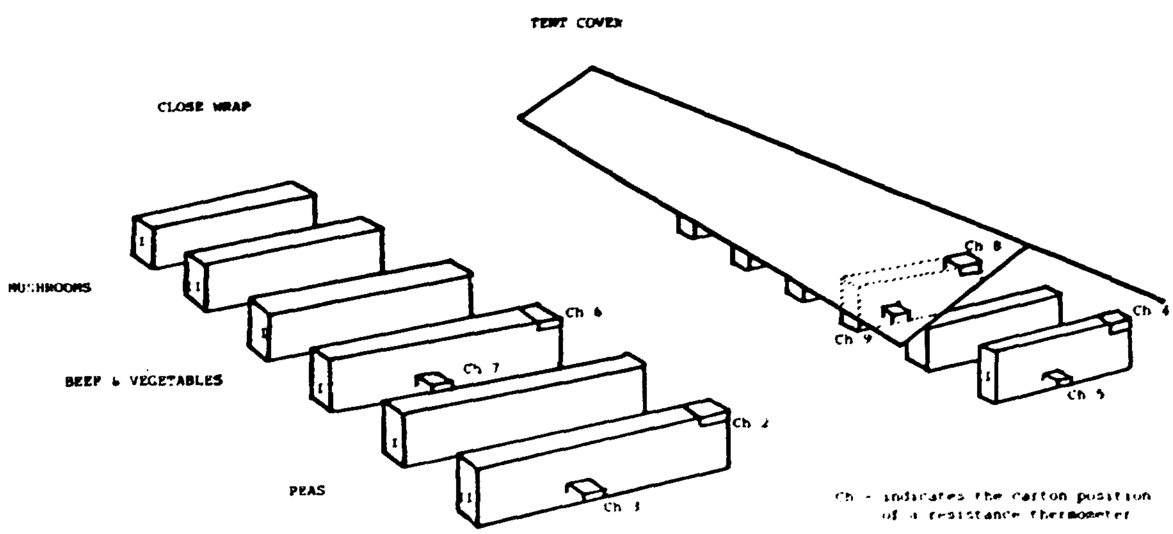


Fig. 2 Diagram showing Stack positioning of Cartons.

D. Estimation of the Area of Can Corrosion

The area of corrosion was taken as that area in which detinning had occurred, allowing rust to develop on the steel substrate from its exposure to the humid atmosphere.

Image analysis (Duncan, 1985) was used to determine the percentage area of corrosion of sixteen representative cans exhibiting a range of surface corrosion. Each can was open at both ends, the body slit at the side seam and rolled flat. The can section was then evenly illuminated and a digital image obtained using a video based IBAS image analysis system. The continuous tone digital image (Photo 2) was further treated to discriminate out the grey levels related to the areas of corrosion.

Photo 2 Continuous tone digital image.

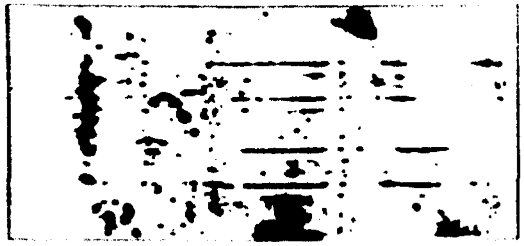


Photo 3 Discriminated binary image used to calculate percentage area of corrosion.

The discriminated image (Photo 3) was obtained by creating a binary image of the corrosion at the lowest detectable grey level threshold below the tin background grey level. The grey level threshold was set constant for all cans assessed. Once the discriminated area of corrosion was obtained, the ratio of its area related to the specimen's total area, yielded the percentage area of corrosion (Hatt, 1985).

Sixteen can bodies and ends, with areas of corrosion ranging from 0.5% to 26%, measured by image analysis, served as reference standards. These reference standards were used when visually estimating the percentage corrosion on the remaining cans. Cans having a possible area of corrosion below the threshold measurable value of 0.5% were regarded as corrosion free. The corrosion value recorded for the end of each can, was of that end which had the greater amount of rust. Usually the top end, had the greater rust area.

E. Estimation of Corrosion Pit Depth

Corrosion pit depth measurements on representative samples were made by direct focussing on the pits, using a calibrated microscope with dark field illumination. Further pit depth measurements were made on a polished microsection, using a calibrated microscope and bright field illumination.

F. Lacquer Adhesion

Tests on both the lacquer and lacquer adhesion of Trial samples were performed as detailed in Appedix A of ADFFS 15-6-1 Lacquer, External.

G. Temperature and Humidity Recording

The temperature of representative cans (Fig 1) were recorded hourly using RTD resistance thermocouples linked to a M200L Microdata Cassette Data Logger. Relative humidity and ambient temperature readings were similarly recorded at the meteorological station, adjacent to the test site.

RESULTS AND DISCUSSION

Summaries of the Areas of Corrosion for each stack are listed in Tables 1 and 2.

TABLE 1

Percentage Area of Rust — Can Bodies

The Means, Maximum and Minimum Values, and Standard Deviations for % Area of Rust on Can Bodies, for each Carton Stack.

	TREATMENT											
COVER	CLOSE WRAP						TENT COVER					
PRODUCT	BEEF		MUSH		PEAS		BEEF		MUSH		PEAS	
STACK	I	II	I	II	I	II	I	II	I	II	I	II
Mean (X)	0.24	0.21	2.01	2.77	2.75	2.56	0.21	0.11	0.49	0.63	1.54	3.07
Min.	0	0	0	0	0.5	0.5	0	0	0	0	0.5	0.5
Max.	1.5	2.5	15	8.5	8.0	7.0	1.5	1.5	3.5	4.0	4.0	30
STD DEVIATION	0.33	0.36	1.87	1.82	1.35	1.24	0.31	0.25	0.55	0.92	0.73	2.55

TABLE 2

Percentage Area of Rust — Can Ends

The Means, Maximum and Minimum Values, and Standard Deviations for % Area of Rust on Can Ends, for each Carton Stack.

	TREATMENT											
COVER	CLOSE WRAP						TENT COVER					
PRODUCT	BEEF		MUSH		PEAS		BEEF		MUSH		PEAS	
STACK	I	II	I	II	I	II	I	II	I	II	I	II
Mean (X)	0.10	0.05	0.62	1.58	0.19	0.27	0.14	0.13	0.33	0.20	0.60	2.00
Min.	0	0	0	0	0	0	0	0	0	0	0	0
Max.	1.5	1.4	7.0	6.0	30	3.0	3.5	6.[illegible]	6.5	5.0	25	40
STD DEVIATION	0.24	0.16	0.96	1.37	1.87	0.54	0.52	0.71	0.66	0.55	2.89	5.40

The average means from Tables 1 & 2 indicated that the rusting was in the order Peas (1.6%) > Mushrooms (1.1%) >Beef & Vegetables (0.2%), and Close Wrap (1.1%) > Tent Cover (0.8%).

Analysis of variance for both bodies and ends showed that the Lacquer and Cover did not have significant effects because of the large variation between stacks of the same product. Also the Area of Rust values (%) are not normally distributed, due to the large number of values < 0.5%. A log transformation of these values did not improve the normalcy of the data or the significance of the main factors of Cover or Lacquer.

Some especially singularly high values for rusting were caused by leakage from improperly sealed or damaged cans (Photo 4). This leakage, corroded neighbouring cans in a 'multiplier effect'. Unusually severe rusting also occurred on can ends adjacent to the gap between carton flaps (Photo 5).

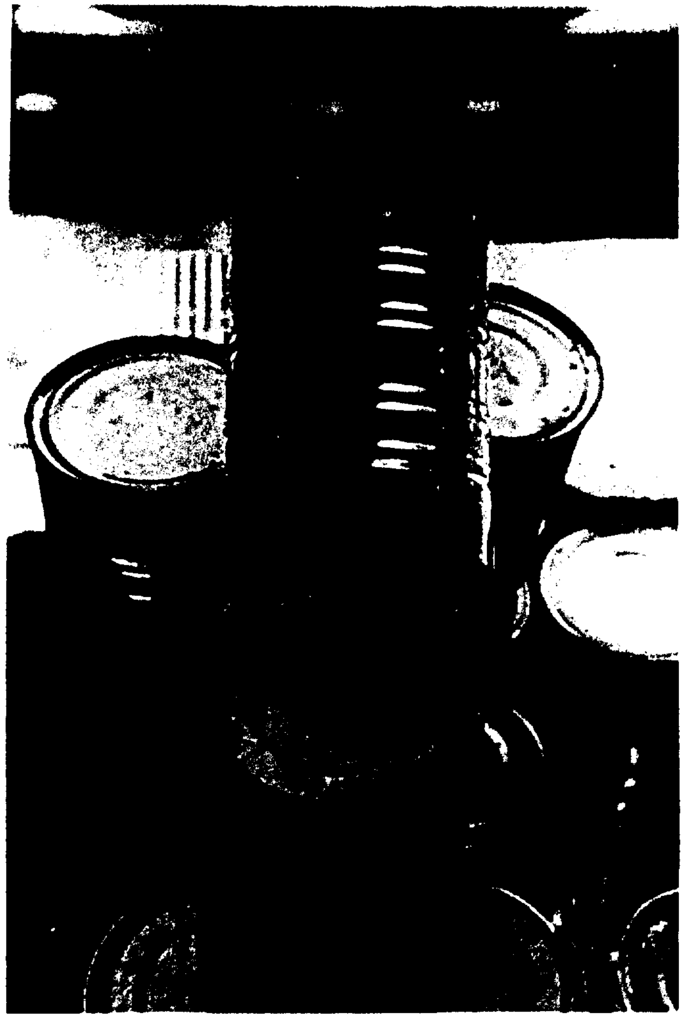


Photo 4 Leakage from an imperfectly sealed can

Photo 5 Excessive corrosion occuring on can ends at the gap between carton flaps.

The corrosion occuring at this gap was most severe in Tent Cover Peas, stack II (Tables 1 & 2), and is attributed to moisture and salt spray entering from the southerly 'weather side' of the tent (Marian, 1986). About 1% of the cans showed this condition.

These abnormally affected cans (Photos 4 & 5) termed 'Rejects', although of significance, are not representative of the reactions of normal cans to storage conditions under evaluation in this trial.

It is assumed that the incidence of "gap" rusting would be less in Army ration packs, beacuse the cartons used for Ration packs are made from heavier grade cardboard with overlapping carton flaps and they have carton dividers. The packing of cans in single layers and use of carton dividers to separate cans, minimises the spread of corrosion from a leaking can (Photo 4) within ration pack cartons.

TABLE 3

Percentage Area of Rust — Can Bodies, without Rejects

The Means, Maximum and Minimum Values, and Standard Deviations for % Area of Corrosion of Can Bodies, for each Carton Stack.

	TREATMENT											
COVER	CLOSE WRAP						TENT COVER					
LACQUER	BEEF (BCW)		MUSH (MCW)		PEAS (PCW)		BEEF (BTC)		MUSH (MTC)		PEAS (PTC)	
REPLICATE	I	II	I	II	I	II	I	II	I	II	I	II*
Mean (X)	0.24	0.21	1.76	2.26	2.60	2.48	0.21	0.11	0.45	0.48	1.50	2.69
Min.	0	0	0	0	0.5	0.5	0	0	0	0	0.5	0.5
Max.	1.5	2.5	5.5	5.5	7.0	5.0	1.5	1.5	2.0	3.0	3.0	7.0
Std Deviation (Sx)	0.34	0.36	1.28	1.17	1.10	1.11	0.31	0.25	0.46	0.71	0.65	1.19

* Weather affected

TABLE 4

Percentage Area of Rust — Can Ends. Without Rejects

The Means, Minimum and Maximum Values, and Standard Deviations for % Area of Corrosion of Can Ends, for each Carton Stack.

	TREATMENT											
COVER	CLOSE WRAP						TENT COVER					
LACQUER	BEEF (BCW)		MUSH (MCW)		PEAS (PCW)		BEEF (BTC)		MUSH (MTC)		PEAS (PTC)	
REPLICATE	I	II	I	II	I	II	I	II	I	II	I	II*
Mean (X)	0.09	0.05	0.53	1.35	0.05	0.26	0.05	0.05	0.27	0.17	0.18	0.79
Min.	0	0	0	0	0	0	0	0	0	0	0	0
Max.	1.5	1.4	3.0	4.0	1.0	1.5	1.5	1.5	2.0	2.0	2.0	5.0
Std Deviation (Sx)	0.24	0.16	0.70	1.11	0.23	0.38	0.18	0.18	0.39	0.40	0.29	0.93

* Weather affected

Inspection of Tables 3 & 4 indicates variation between stacks of the same product. The average mean values in Tables 3 & 4 again indicates the severity of corrosion in the order Peas>Mushroom>Beef & Vegetables, and Close Wrap>Tent Cover.

The results in the above Tables reveals two abnormalities. The first is the high level of rust in stack II of Peas Tent Cover. Site inspection of the stacks revealed greatest weather discolouration of these Peas, Tent Cover, Stack II (PTC II) Pea cartons, consistent with advice from Marian (1986), that south is the weather side of this site.

This end stack was the most exposed and thus 'weather affected', whilst shielding the adjacent stacks. This would indicate that for products stored under this style of Tent Cover, the outermost stack(s) may need additional protection, whilst still allowing air circulation through the tent.

Figs 4 and 5, depict the per cent frequency and areas of rust of the three products, with each pair of replicate stacks combined. Stack II Peas, Tent Cover was excluded, due to its position as the most weatherward stack, consequently receiving higher corrosive action (Table 4).

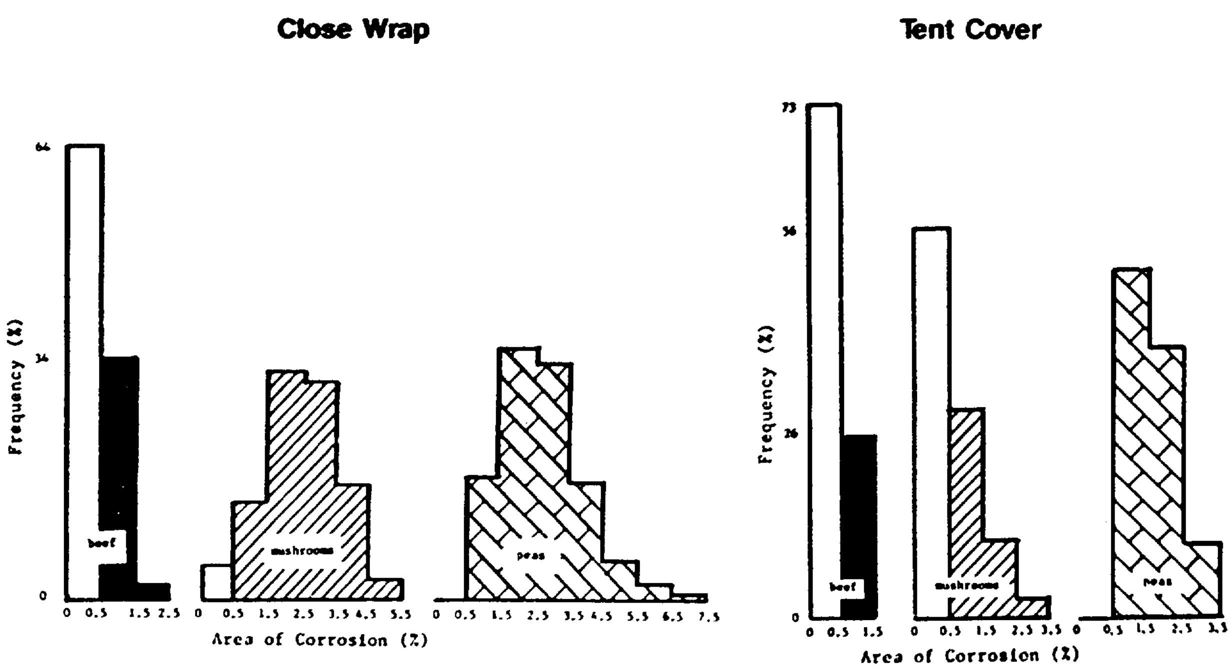


Fig 3 Extent of Corrosion on Can Bodies, depicting Can Frequency (%) with Areas of Corrosion (%). Rejects and Tent Cover Peas stack II, omitted.

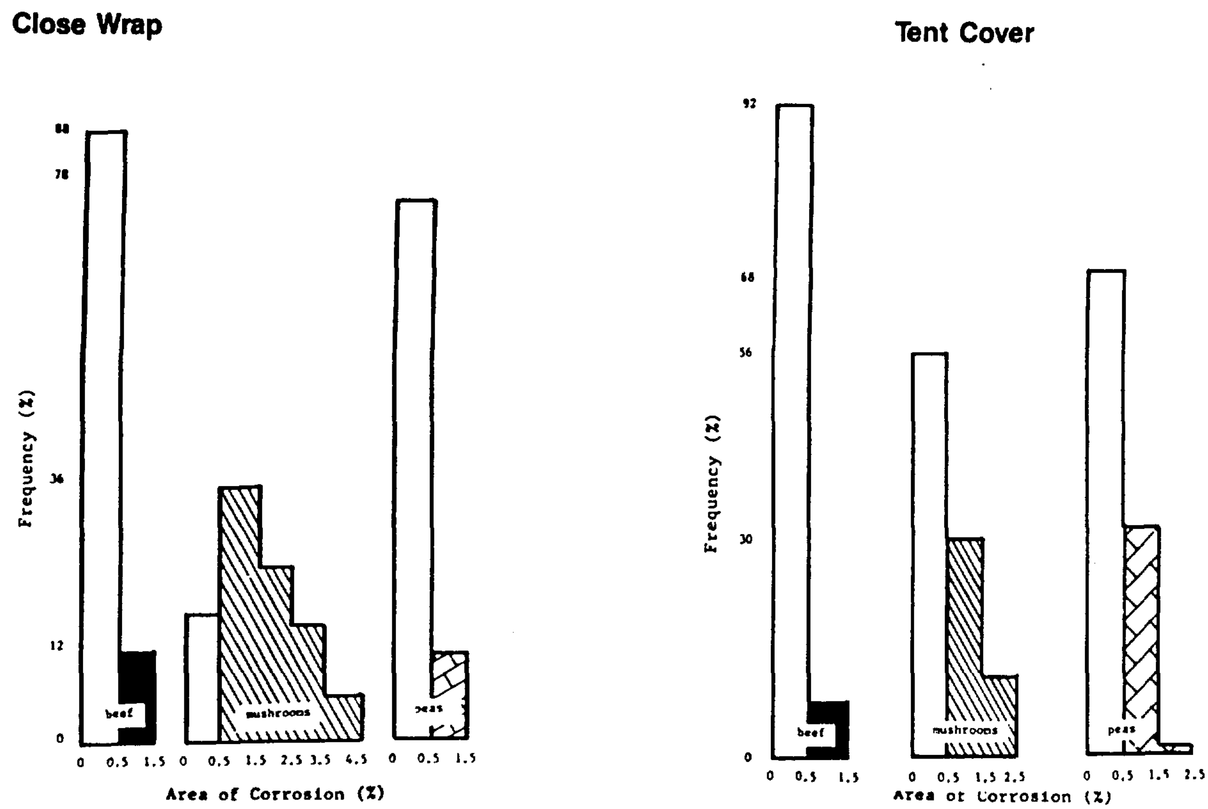


Fig 4 Extent of Corrosion on Can Ends, depicting End Frequency (%) with Areas of Corrosion (%). Rejects and Tent Cover Peas stack II, omitted.

The other obvious abnormality is that there is more rust on the Mushroom cans than on the Beef cans. These products, though manufactured at different factories, were externally lacquered on the same occasion.

The rust on the cans of Mushrooms had a thread-like or filiform appearance (Photo 6). These cans may have been damp when lacquered, because they were lacquered immediately after processing.

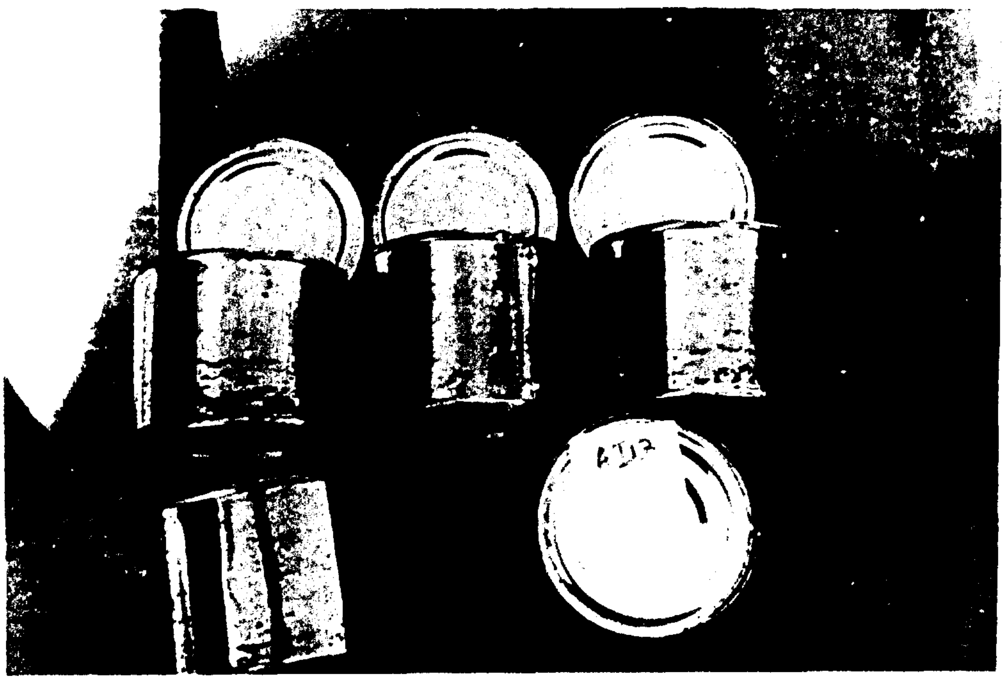


Photo 6 Lacquered cans of Mushrooms showing 'filiform' corrosion.

The Gold Can Dipping Lacquer as used on these cans was found to be satisfactory when tested by the Materials Testing Laboratories (MTL) against ADFFS (1979).

MTL (Kenny, 1986) examined representative cans from the trial. Lacquer adhesion varied from almost non-adherent to adherent on the Mushroom cans. The coating was found to be brittle and non-uniform in thickness. There were numerous scratches in the lacquer through to the metal surface, allowing moisture penetration and causing further adhesion loss. This lack of adhesion, unevenness of coating, and the red corrosion is consistent with the application of the lacquer over a damp surface.

When the Beef cans were subjected to the same tests, the lacquer remained adherent and free from the ingress of moisture, even though the coating had similar scratches to those on the Mushroom cans.

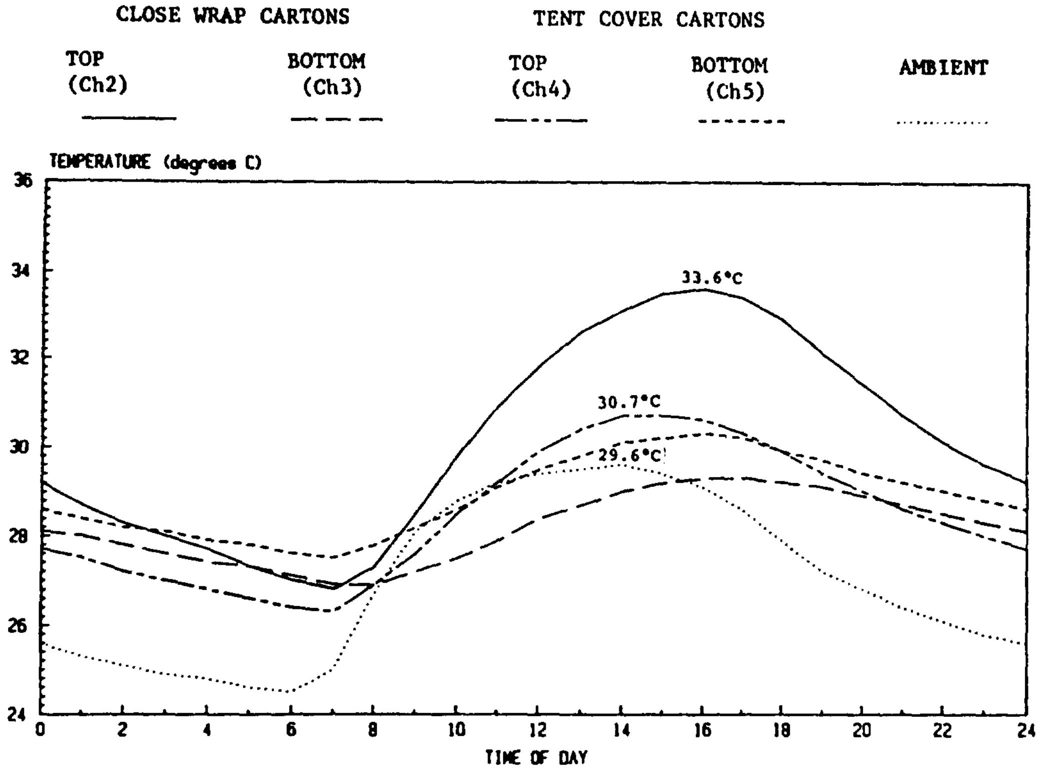
Condensation

During stack inspections, condensation was observed on Close Wrap cans, particularly in the middle and bottom layers of cartons.

Figure 5 shows the mean temperature of eight cartons and the mean ambient temperature, over the total trial period. For 7 hours a day (on average) the bottom layer of cartons in Close Wrap stacks were below ambient temperature. Hence when the relative humidity approached 100%, the surface of cans in these cartons would be below the dew point and condensation probably occurred. The average humidity for the total period was 89.4% r.h. Hall *et al* (1982) state that "on a really humid day (say 90% r.h.) can surfaces only 1.5° to 2°C below the air temperature, will show condensation." Observed condensation was heaviest on those parts of the can body facing the vertical air gap between cans (Photo 7). This produced areas of rust as vertical bands (Photo 8) particularly on the unlacquered Pea cans.

Photo 7 Condensate formed on the vertical sections of the can body facing the air gap between neighbouring cans.

6a. Outer Stacks (Peas II)



6b. Inner Stacks (Beef & Veg II)

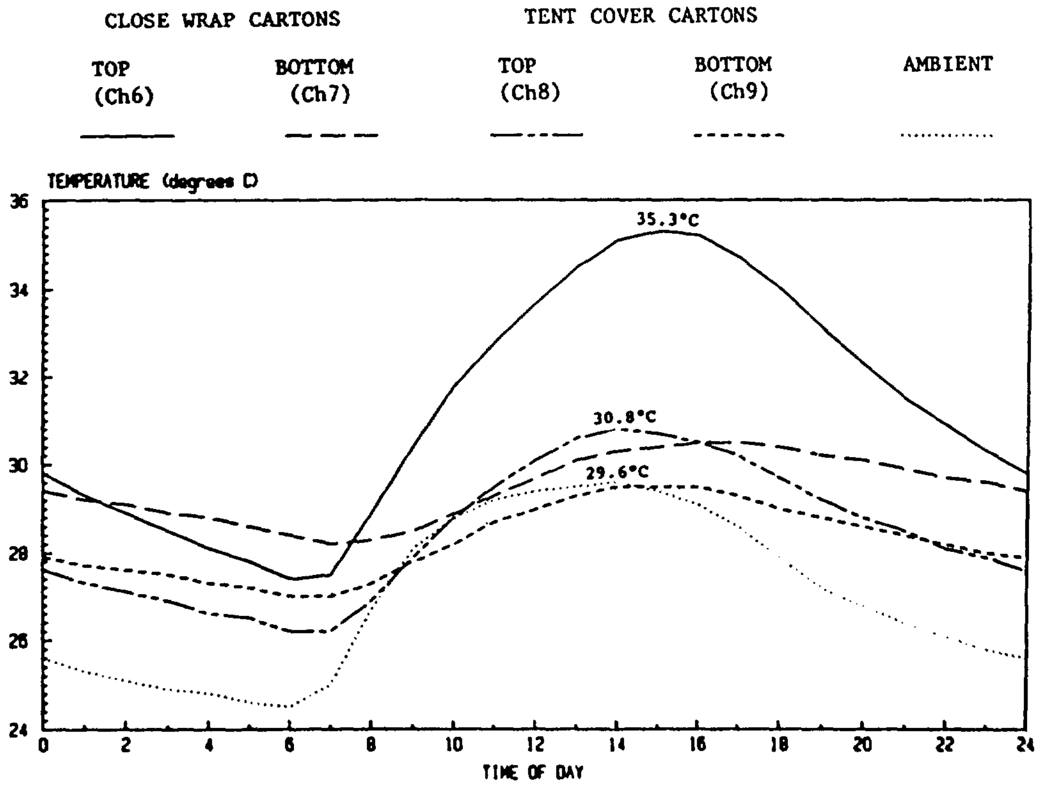


Fig 6 Hourly Mean Stack Temperatures

Photo 8 Rust on the vertical sections of the can body facing the air gap between neighbouring cans

Table 5 lists the mean areas of rust found on all cans in both the top and bottom layers of cartons, under both Close Wrap and Tent Cover storage.

Results from this table support those observations made on condensation, by indicating that the bottom carton layer under Close Wrap, had the highest mean value for rust. Conversely for Tent Cover, more rust occurred in the top cartons, though the values for both Tent Cover layers were lower overall than for Close Wrap.

TABLE 5

Percentage Area of Rust, Means of all Cans in the Top and Bottom Layers of Cartons, under both Covers

	BODIES		ENDS	
	CLOSE WRAP	TENT COVER	CLOSE WRAP	TENT COVER
Top cartons	1.50	1.10	0.30	0.35
Bottom cartons	1.75	0.75	0.55	0.25

Photo 9, (Peas, unlacquered) and Photo 10 (Mushrooms, poorly lacquered) show cans from the bottom layers of cartons from Close Wrap and Tent Cover. The measured areas of rust are also shown. The results show that Tent Cover stacks have less condensation and lower levels of rust than Close Wrap stacks.

These photographs also show that areas of rust as low as 0.5% to 1%, may give the can an objectionable appearance.

7.3% (C.W.) 1.0% (T.C.) 6.7% (C.W.)

Measured area of body corrosion

Photo 9 Rust development on unlacquered Pea cans. These cans were taken from equivalent locations under Close Wrap (C.W.) and Tent Cover (T.C.).

2.6% (C.W.) 0.5% (T.C.)

Measured area of body corrosion

Photo 10 Rust on poorly lacquered Mushroom cans. These cans were taken from equivalent locations under Close Wrap and Tent Cover.

Depth cf Corrosion Pits

The thickness of the tinplate and the depth of pitting was measured by MRL (Mourant 1986) on cans showing substantial areas of rust.

The results of these measurements are listed in Table 6.

TABLE 6

THICKNESS OF TIN PLATE PIT DEPTH
OF CORRODED CANS
(Measurements in microns)

SAMPLE	THICKNESS BY MICROMETER	PIT DEPTHS			
		DARK FIELD		BRIGHT FIELD	
		Range	Average	Range	Average
Under Close Wrap					
1. Peas	237	44-72	58	32-135	40
2. Peas	232	18-41	25	7-25	13
3. Mushrooms	251	34-51	41	21-82	47
4. Mushrooms	249	-	-	11-21	15
5. Beef	246	36-72	55	-	-
6. Beef	237	29-51	40	21-153	55
Under Tent Cover					
1. Peas (lid)	274	-	-	7-21	11
2. Mushrooms	213	39-108	67	-	-
3. Mushrooms	216	48-82	70	-	-
4. Mushrooms	229	41-92	57	-	-
5. Beef	224	58-116	89	-	-
6. Beef	262	19-49	35	-	-

Mourant (1986) commented that "there is a real danger of can spoilage if these cans are subject to impact loading (knocking or dropping), when the observed pits are approximately 50% of the can wall thickness."

Non Metallic Inclusion

One example of can perforation (end) arising from a foreign particle or impurity in the steel plate was detected. This was subsequently verified by Nicholson (1985) who described the defect as a 'non-metalic inclusion' and advised that its incidence is very low.

CONCLUSIONS

The observations on the extent and distribution of external rusting on the canned foods stored at the JTTRE, Cowley Beach site, and subsequent measurements at AFFSE and at MRL showed that:

1) Cans having a 05 external tin coating may be stored under field conditions in the tropics for at least 23 weeks if the tinplate is properly protected by an external lacquer and the stocks of cartons are protected from the direct effects of the weather.

2) Unacceptable levels of external rusting occurred on cans that had not been lacquered externally and cans that had been unsatisfactorily lacquered, e.g. the lacquer had been applied before the cans had completely dried after processing.

3) Rusting was most severe where the ends of the cans were exposed to the atmosphere at the gap between the flaps in the cartons and where the cylindrical surface of the can bodies faced the free space in the cartons.

4) Diurnal changes in the temperature in the cartons were sufficiently large in the humid conditions at Cowley Beach to cause condensation on the cans; large amounts of condensate were seen in some stacks under close wrap cover. The temperature changes were larger in the close-wrapped stacks than in those stacked under the tent cover.

5) The stacks of cartons nearest the open ends of the tent require additional protection from the direct effects of the weather, e.g. salt spray being carried into the tent by the wind.

6) Many cans were rusted to the extent that they would probably be rejected by Service personnel under ordinary conditions. There was evidence that the rust had caused pitting of the tinplate. Consequently perforations would probably have occurred after long storage.

RECOMMENDATIONS

Tinplate

As 05 bright tinplate did not provide sufficient corrosion protection for these Armed Forces conditions of storage and handling, the adoption of a lower tin mass external can coating should be resisted, pending further evaluation.

As a consequence of the decreasing use of E05 tinplate and cans for the retail market, any procurement difficulties for E05 cans, should be overcome by Logistic Command advising the two canmakers and BHP of ration can requirements for the coming year.

It is also recommended that for field storage, canned foods be stacked off the ground and under a covering which allows adeqaute ventilation, especially across the top of the stack. This is in accordance with Section 4-4, RAASC (1971, para 425). The covering should also protect the stacks from wind-blown rain and spray. Canned foods should not be stored in the field under close wraps.

Future Work

As canners are unable or becoming more reluctant to post process, dip lacquer cans using a petrochemical solvent, the alternative use of a prelacquered can should be evaluated. The two major aspects to be considered in this evaluation would be selection of the most appropriate lacquer type and overcoming damage to the lacquer continuity during canning. The Defence Force requirements of a lacquer are that it be impervious, tough, flexible, adhesive, pigmented and preferably non-reflective (matt).

It is suggested that new developments in surface coating technology be explored with the aim of finding better methods for protecting cans from rusting under conditions encountered during storage and transport by the Services. Facilities for testing the rust resistance of new external lacquers on various types of tinplate are available at the AFFSE and MRL.

Selection of the most appropriate lacquer system is usually left to the canner or buyer, from their own product test pack trials. It is recommended that a co-ordinated selection be made involving Army, MRL (Paints Group), a Canning Industry representative and AFFSE to obtain the most appropriate external lacquer system. AFFSE, from its association with the above groups and the food canning industry, should co-ordinate this evaluation.

Alternative methods, to protect cans against external rusting, should be explored. The feasibility of shrink wrapping inside or outside the carton; or using a plastic liner in the carton; or using cartons that are made from PVDC-coated or waxed fibreboard should be determined. These systems put the moisture barrier around the carton of cans rather than around each can. They may be preferred approaches, if the canning industry continues to be reluctant to properly apply external lacquers. These alternative approaches should be discussed with carton manufacturers and technical staff.

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